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Engaging scientists in science communication: The effect of social proof and meaning

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ABSTRACT

Science communication helps the general public understand science breakthroughs, making them support evidence-based decision making. Therefore, science communication is of paramount importance for issues that closely relate to the public, such as sustainability, climate change, and environmental behaviors. The degree of scientists' involvement in science communication, however, is often inadequate in China. This article considers scientist engagement as a two-stage process consisting of participation and effort and then explores the causal effects of social factors in this process. Based on a field experiment with Chinese scientists, we find that, as social proof, information of peers' engagement significantly increases scientists' participation, but not their real efforts made in science communication; in-group meaning, which emphasizes the benefits of scientist communication to the science community, does not induce more participation but significantly increases average efforts of participants. A combination of social proof and in-group meaning can lead to greatest efforts of scientists to communicate with the general public.

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1. Introduction

Environmental and sustainability challenges call for more effective science communication nowadays. Public support for climate action depends on the way that scientific messages are framed and communicated (Spence and Pidgeon, 2010) and public perception of consensus among scientists (Ding et al., 2011; Lewandowsky et al., 2013). Sustainable development requires the design of communication interface where universities play an important role (Adom ßent, 2013). Science communication can help the public follow science advancement and increase both their own action and support for science-based decision making that tackle climate change and sustainability issues. For developing countries like China, other issues also worth science communication, such as food safety (Mou and Lin, 2014), air pollution, and "Not In My Backyard" attitude toward industrial development. Here, scientist communication helps to eliminate misrepresented information, reduce public anxiety, and mobilize policy support.

Scientist involvement in science communication, however, is not always sufficient and effective. Climate scientists, for example, are considered not able to well communicate IPCC's Fifth Assessment Report (Hollin and Pearce, 2015). While China observed increasing public demand for scientific knowledge and generous government funding of science and technology projects, scientist engagement in science communication is still insufficient, with the scientific community being characterized as "unenthusiastic scientists" (Wu and Qiu, 2012; Zhang, 2015). Therefore, it is important to investigate how to motivate scientists to participate and exert more efforts in science communication.

This article is based on a field experiment with scientists at tier-one Chinese universities, observing their participation decisions and effort-making behaviors in science communication. We find that both social proof and in-group meaning to the scientist community promote scientist engagement in science communication, but their effects apply to different stages of scientist engagement. A

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combination of the two strategies best facilitates scientists' communication with the public.

This article contributes to the literature in four ways. First, the current sustainability communication research focuses mainly on the detailed means and strategies for sustainability education (for example, Hoveskog et al., 2017; Kapitulčinová et al., 2017), without much attention to the motivations and efforts of scientists in broader communication activities. Second, the study provides a structural view of science communication process. An in-depth understanding of the process calls for a focus on both participation and the amount of effort that a scientist put into action. Third, by investigating the effect of social proof and meaning on scientists' two-stage public engagement process, the study shifts the attention of science communication research from individual scientists and organizational level factors to social factors with a specific focus on two significant others: peers and beneficial groups.

Last but not least, this article establishes the causal relationship between social proof, meaning, and the science communication process. The field experiment method used in this research overcomes many of the issues associated with survey methods. Field experiments establish clear causal effects and are a major source of knowledge creation in the social sciences (Falk and Heckman, 2009). Our findings based on the field experiment generate important policy implications: the inexpensive, easy-to-implement measures that we adopted are an efficient instrument to facilitate science communication in developing countries like China; they help to consolidate support for sustainability and climate policies and to mitigate irrational environmental concerns.

2. The process of scientist engagement in science communication

We refer to science communication more formally as public engagement in our research. Public engagement is one of the social responsibilities of scientists, representing their communication activities to engage in dialogue and interaction with members of the public outside of a classroom setting (Bauer and Jensen, 2011; Poliakoff and Webb, 2007). Public engagement is expected to produce one or more of the following personal responses to science: awareness, enjoyment, interest, opinion forming, and understanding (Burns, O'Connor and Stocklmayer, 2003). It encompasses a range of activities, including public lectures, media interviews, and public debates. When scientists engage in such activities and communicate scientific knowledge to the public, they may aid people in reaching better decisions on health, happiness, and their own lives. These activities can also create favorable attitudes toward science among policymakers as well as help to generate excitement among young people who may have not considered a career in science (Treise and Weigold, 2002).

Extensive research has sought to explore the factors motivating scientists to participate in science communication. Among these are individual level factors, including academic status, discipline, perceived norms, and gender (Dunwoody et al., 2009; Poliakoff and Webb, 2007; Tsfati et al., 2011), as well as organizational level support (Marcinkowski et al., 2014; Neresini and Bucchi, 2010). These factors significantly predict a scientist's science communication intention (Besley, 2014; Poliakoff and Webb, 2007) or self-reported actual science communication behaviors (Besley et al., 2012; Dudo, 2012; Marcinkowski et al., 2014).

Previous research has focused solely on participation intentions and frequency of self-reported behaviors. However, the intention to participate or a self-reported behavior does not necessarily translate to effective communication. Effective communication requires scientists not only to be motivated to participate, but also to exert labor and cognitive efforts (Bracha and Fershtman, 2013). These efforts could help scientists understand the information demanded by the public and the most effective way to communicate science information (e.g. choosing the most appropriate media, Illes et al., 2010). Thus, this article not only examines a scientist's decision to participate, but also incorporates his/her choice on the amount of efforts to be put in these activities.

In short, this article aims to contribute to the science communication literature by considering scientists' public engagement in science communication as a process that includes participation and effort making. Thereby, the article seeks to advance understandings of the factors that motivate scientists to engage in science communication in a more refined way.

3. Social factors that promote scientist public engagement

This article focuses on two social factors that may influence scientists' public engagement process, namely, social proof and meaning. Social proof refers to the act of presenting individuals with responses of others in a given situation. Individuals have a tendency to seek social proof and "view a behavior as correct in a given situation to the degree to which one sees others performing it" (Cialdini, 1993: 95). Labor or a set of tasks is viewed as meaningful to the extent that (a) it is recognized and/or (b) has a purpose (Ariely et al., 2008). Thus, in this study we focus on how information of the behavior of scientists' peers (i.e. social proof) and benefits that their actions bring to other groups (i.e. meaning) influence their decision-making process. Both peers and beneficial groups are a scientist's "significant others."

3.1. Social proof

As a type of social proof, informing a scientist of other scientists' participation in public engagement may increase his or her intention to participate. One of the impediments of scientists' public engagement is the fear to be viewed negatively by others (Ecklund et al., 2012; Gascoigne and Metcalfe, 1997; Johnson et al., 2014). For instance, physicists view science communication a possible threat to reputation (Johnson et al., 2014). Meanwhile, according to a survey conducted by the Royal Society (2005), 20% of scientists worried that, by engaging in public activities, they would be viewed negatively by their peers. According to the principle of social proof, people look at the responses of others to determine what constitutes an appropriate action (Armitage and Conner, 2001; Asch, 1956; Cialdini and Goldstein, 2004), especially when they face uncertainty in decision making (Rao et al., 2001). Moreover, the presence of social proof is found to be more influential when people learn the behavior of their affinity group (Cialdini et al., 1999). In this way, social proof of peers' participation may mitigate scientists' concerns that they will be viewed negatively and make them recognize the value of such activity. In addition, social proof may increase participation simply because scientists imitate their peers' action. Therefore, we propose that scientists would have a higher intention to participate when knowing their peers's participation in public engagement.

The above hypothesis is supported by previous research that found injunctive normative perceptions (whether peers endorse a particular behavior) and descriptive norms (majority of peers conduct such behavior) as predictors of scientists' intention to participate in public engagement (Besley, 2014; Dudo, 2012; Besley, Dudo and Storksdieck, 2015). It should be noted, however, that social proof is different from social norms. Norms emphasize what the "majority" think as right and follow and are usually associated with perceived social pressure to perform or not to perform a behavior (Ajzen, 1991). Thus, social proof is a weaker intervention compared with norms.

The effect of social proof on a scientist's efforts in public engagement, however, may not necessarily be the same as its effect on participation. Social proof can mitigate scientists' concern to be viewed negatively by their peers in participation. But effort-making is more than simply a dichotomous choice of whether to participate. Rather, effort-making may require stronger motivation, so that the content of information carried in social proof is important. If one only provides information about other scientists' participation instead of effort, then one should not expect it will impact scientists' effort making. Meanwhile, if social proof principle serves only as a heuristic and decision makers passively imitate peers' action (Rao et al., 2001), then we expect it is not strong enough to make scientists exert efforts. So our first hypothesis states:

H1: Social proof (Informing scientists of their peers' participation) will increase their intention to participate but not necessarily their efforts in public engagement.

3.2. In-group and out-group meaning

The notion of meaning captures the degree to which an act provides opportunities to improve the welfare of others (Grant, 2008). It is regarded as the primary motivational force of an individual (Frankl, 2006, p. 99). For instance, fundraising callers were able to raise more funds when they received positive information on the impact of funds they raise on others (Grant, 2008). Workers on Amazon's Mechanical Turk were more likely to participate in a work assignment and increased the quantity of output if they knew their work serves a purpose such as assisting medical researchers (Chandler and Kapelner, 2013).

We distinguish theoretically two types of meaning based on beneficiaries' groups from scientists' public engagement. These two types are meaning toward scientists' community (in-group meaning, hereafter) and the public and decision makers (out-group meaning, hereafter). For in-group meaning, public engagement brings benefits to scientists in general as it facilitates mutual understanding and empathy between the public and scientists, which, in turn, improves public perception of scientists (Hughes, 2001; Poliakoff et al., 2004). Public engagement activities also enhance scientists' influence and social position (Besley, 2014). The public would be more supportive of scientific research if scientists disseminate information of their discoveries to wider audiences (Greenwood and Riordan, 2001).

For out-group meaning, more scientists' public engagement would help increase the public's science literacy, which can lead to better decision making in the lives of the public. In dealing with complex science-related policy issues, policymakers would also benefit from communication with scientists.

The two beneficiary groups differ in social distance from a focal scientist. According to the social identity theory (Tajfel and Turner, 1979), people categorize others and themselves into basic categories, for example according to race and religion, and then associate themselves with certain groups. In-groups are groups as which people are identified, whereas out-groups are those outside their self-identification. For a scientist, the science community is categorized as an in-group, whereas the public and policymakers as an out-group. Numerous studies have suggested that people exhibit favorable bias toward in-group than out-group (Brewer and Gardner, 1996; Dovidio et al., 1997; Sudhir et al., 2016). A scientist is more likely to feel greater empathy and responsibility to the science community. In-group meaning enhances a scientist's belief that public engagement will have an impact on the science community, thus increasing his/her external efficacy. The enhanced external efficacy further leads to positive attitude toward public engagement and increased levels of engagement by scientists (Besley, Oh and Nisbet, 2012). Thus, this article postulates that a scientist is more motivated to engage in public engagement when he/she perceives in-group meaning of public engagement.

In contrast, previous studies suggest that scientists may hold a range of negative views on the public. A dominant view sees the public as having limited knowledge of science and generally not interested in learning anything new (Blok et al., 2008; Burningham et al., 2007). Scientists also worry that they will be mistreated by the media and the public (Crichton, 1999), and are reticent toward engaging with members of the public, including both decision makers and different sectors of the society (Besley et al., 2012). Hence, depicting the meaning of public engagement as increasing benefits to the public and policy-makers may spur concerns, preventing a scientist to participate or exert more efforts in public engagement. Therefore, the following two hypotheses state:

H2a: In-group meaning of scientists' public engagement will increase their intention to participate and their efforts made in public engagement.

H2b: Out-group meaning of scientists' public engagement will not increase their intention to participate or their efforts made in public engagement.

4. Experiment design

4.1. Selection of respondents

We focus on professors in science and technology disciplines at all the tier-one universities in China. These universities are those selected into the 985 project, which aims to develop world-class universities in China and includes 39 universities. As there is no existing database of the professors, research assistants were hired to manually collect information on all the available faculty webpages of the universities. This step resulted in a list of 31344 scientists, including information of their institutions, academic ranks, disciplines, gender, and e-mail addresses. For feasibility concerns, 3000 of the 31344 scientists were randomly sampled for a field experiment. Professors at top universities constitute a dominant part of scientists in China. Their research ability and experience are the basis of science communication, which enables them to play a major role in the science communication landscape in China.

We conduct the experiment with the professors and apply treatment through emails. An e-mail is an open information and identifier for each scientist. E-mail is used as a common way to contact or invite scientists to participate in public engagement activities as they are used to being invited rather than taking the initiative to speak in public. Using e-mail can also keep the identities of the scientists from being disclosed, mitigating their concerns about risk. A similar method has been applied by previous studies in studying the responsiveness of county governments (Chen et al., 2015) and potential donors' response to donation requests (Feiler et al., 2012). In addition, the emergence of new forms of media paved the way for online communication to become a main method of science communication. As Zhang (2015) pointed out, scientists in China increasingly prefer to act as “informal” communicators in grassroots and private events rather than in formal and public ones. For instance, scientists in China express their opinions via their blogs or answer people's questions directly on general and specialized online forums (e.g., Zhihu.com and other medical forums). Thus, this field experiment design is consistent with China's science communication background and scientists' public engagement situation.

4.2. Experiment procedure

The experiment was conduct in October 2015. Scientists were invited to provide their answers to 100 questions on science and

science communication, without providing any reward. Treatment was introduced by varying the content in the e-mail that each scientist received, which is further illustrated in the next session. During the process, a scientist makes two-stage decisions. After reading the e-mail, a scientist could click on the hyperlink and land on the Qualtrics page, a widely-used platform for online surveys and experiments (see Knobloch-Westerwick et al., 2013), where the survey was set up. Clicking the hyperlink means the scientist has already shown intention to participate. On the Qualtrics page, 100 questions were presented to the scientist, who could either fulfill this communication activity by answering all the questions or quit in the middle of the process. Our pilot study showed it took about 20 min to finish all the 100 questions. Finishing all the 100 questions demonstrates exerting full effort. Two dependent variables, which characterize scientists' public engagement process, were tracked: (1) scientists' intention to participate and (2) efforts exerted in public engagement.

The scientists' intention to participate in public engagement, demonstrated by clicking the survey link in the e-mail, was measured dichotomously, where scientists who did not click the survey link were coded "0" and those who did were coded "1." Efforts were taken into account only for scientists who participated. A conservative way to define efforts was employed: a scientist was considered exerting full efforts and coded as "1" if he/she finished all questions; otherwise, he/she was considered not exerting full efforts and coded as "0."

4.3. Treatment

The 3000 scientists were randomly assigned to one of the two conditions of social proof (present or absent of social proof message) and one of the three conditions of meaning (out-group meaning, in-group meaning, or baseline meaning). E-mails that they received followed a fixed format with four parts: a brief introduction of the background of scientists' public engagement, treatment of meaning, treatment of social proof, and the survey hyperlink (see appendix). Except for the treatment, the e-mails were all the same across different treatment conditions. To accommodate scientists from various disciplines, critical topics such as haze and genetically modified foods were used.

The treatment was introduced by varying the treatment of meaning and social proof parts in the e-mails. For social proof, scientists were randomized into treatment and control groups; the former received information of other scientists' participation, whereas the latter received no such information. Scientists in the social proof present condition read, "Our goal is to collect 500 responses. We have collected responses from 317 scientists thus far." Scientists in the social proof absent condition read, "Our goal is to collect 500 responses." This treatment was adapted from Cialdini et al. (1999), who manipulated social proof by telling students that all, half, or no students in the past have complied with the requests. But using the absolute percentage information may result in mistrust or doubt and introduce confounding factors (Anik et al., 2014). Thus, we simply stated the absolute number of their peers that have participated.

For meaning, scientists assigned to in-group meaning condition read the lack of scientists' public interaction would lead to a range of negative outcomes to the community of scientists. In contrast, public engagement will do good to the community such as winning public's trust and support, more research funding, and enhancing scientists' social and political influence. Scientists assigned to out-group meaning condition read that the lack of scientists' public engagement would lead to a range of negative outcomes to the public and policymakers. In contrast, scientists' public engagement will do good to the general public and policymakers such as increasing the public's science literacy, reducing physical and mental harm of pseudo-scientific knowledge to the public, and guiding or correcting the public opinion and public policy. The exact words used in treatment variations are shown in the appendix.

Table 1
Descriptive statistics of sample by Academic status, discipline, and gender.

	Sample: 2946		Population: 31344	
	Frequency	%	Frequency	%
Academic Rank				
Professor	1337	45.4	14,312	45.7
Associate professor	1200	40.7	12,484	39.8
Assistant professor	409	13.9	4548	14.5
Discipline				
Engineering Science	1962	66.6	20,728	66.1
Physical Science	745	25.3	8045	25.7
Agricultural Science	65	2.2	711	2.3
Medical Science	174	5.9	1860	5.9
Gender				
Male	2260	76.7	24,132	77
Female	686	23.3	7212	23

5. Results

5.1. Sample representativeness, randomization and balance

Among the 3000 e-mails distributed, 54 were rejected by the server, which led to 2946 scientists included in the sample. Table 1 presents academic rank, discipline, and gender of the sample. All academic ranks were adequately represented. There were 45% professors, 41% associate professors, and 14% assistant professors in the sample. The respondents were in the fields of engineering science (67%), physical science (25%), medical science (6%) and agricultural science (2%). Majority of them was male (69%). The constitution of the sample of 3000 scientists was similar to the population of scientists. Table 2 describes the covariate balance across control and treatment groups on a number of factors. Randomization was successfully implemented and the treatment was balanced across all the dimensions (all $ps > 0.1$).

Table 3 presents the statistics of opening emails, intention to participate, and exerted efforts across groups. About 27% of the scientists opened the e-mail. The e-mail opening rates were similar across six conditions, which further consolidates the randomness of treatment assignment. On average, about 14% of those who opened their e-mails intended to participate in the study and clicked the link. Less than half of those who participated exerted their full efforts. Table 3 also implies that the intention to participate and efforts vary systematically across treatment conditions. Thus, the effects of social proof and meaning on these two response variables

Table 2
Covariate balance across treatment groups.

Meaning	Baseline		Out-group		In-group		
Social proof	No	Yes	No	Yes	No	Yes	*p*
Professor (%)	46.9	45.0	47.8	46.6	43.3	42.7	0.527
Associate professor (%)	41.1	39.2	37.5	41.1	42.7	42.7	0.517
Assistant professor (%)	12.0	15.8	14.6	12.3	14.0	14.5	0.499
Engineering Science (%)	66.0	68.4	64.9	65.7	66.5	67.9	0.852
Physical Science (%)	5.4	6.2	5.8	6.0	5.7	6.3	0.993
Medical Science (%)	26.8	23.2	26.4	26.2	25.7	23.6	0.694
Agricultural Science (%)	1.9	2.2	2.9	2.0	2.1	2.2	0.921
Female (%)	20.2	26.7	21.9	23.1	22.4	26.5	0.325
Male (%)	79.8	73.3	78.1	76.9	77.6	73.5	0.325

Table 3
Opening, intention to participate, and efforts across groups.

Meaning		Baseline		Out-group		In-group	
Social proof		No	Yes	No	Yes	No	Yes
Total e-mails sent		482	500	485	496	487	496
E-mail Opening rate	# Scientists	130	135	146	119	120	143
	% Scientists	26.9%	27.0%	30.1%	23.9%	24.6%	28.8%
Intention to participate (clicked the link)	# Scientists	12	23	15	23	16	21
	% Scientists	2.5%	4.6%	3.1%	4.6%	3.3%	4.2%
Efforts (answered all questions)	# Scientists	1	11	6	8	8	12
	% Scientists	8.3%	47.8%	40.0%	34.8%	50.0%	57.1%
Efforts (# items answered)		41.25	52.26	55.80	52.48	44.81	69.14

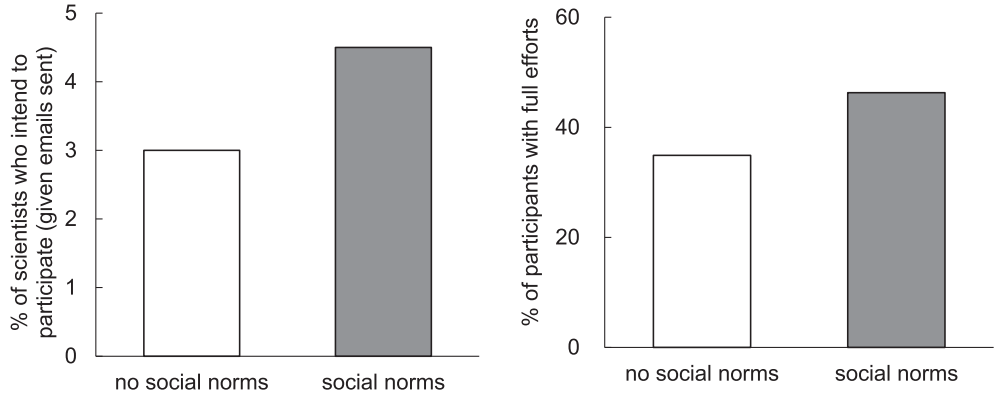

Fig. 1. Social proof causes a significant increase in scientists' intention to participate but insignificant in their efforts.

were examined. For each treatment, statistical comparison between treatment and control groups was provided. A scientist's behavior was linked with the experimental treatment that one received, academic status, discipline, and gender. Regression results of public engagement process on social proof, in-group meaning, and out-group meaning were, thus, generated while controlling for a scientist's academic status, discipline, and gender.

5.2. The role of social proof

Fig. 1 shows the percentage of scientists who intended to participate and exerted efforts conditional on participation across social proof present and absent conditions. Scientists were more likely to participate in the condition with presence of social proof (4.49% or 67 out of 1492 with social proof present, compared to 2.96% or 43 out of 1454 with social proof absent; $\chi^2 = 4.816$, $p < 0.05$, odd's ratio = 1.543). The percentage of scientists who exerted full efforts was lower with social proof absent than with social proof present (34.88% or 15 out of 43 versus 46.27% or 31 out of 67), but the difference was not significant (χ^2=1.395, $p > 0.1$).

Logistic regression was used to test the prediction that social proof of other scientists' participation had positive effect on intention to participate. The independent variables were social proof, in-group meaning, out-group meaning. The control variables were academic rank, research discipline, and gender of a scientist (see Appendix for coding scheme).

Columns (1) and (2) of Table 4 show the regression result of intention to participate, whereas columns (3) and (4) present results of exerted efforts. Columns (1) and (3) include only treatments conditions, whereas columns (2) and (4) also include controls for academic rank, research discipline, and gender. After controlling for the characteristics of the scientists (see column (2) of Table 4),

Table 4
Main treatment effects on intention to participate and exert effort.

Variables	Intention to Participate		Efforts	
	(1)	(2)	(3)	(4)
Social proof	0.434**(0.199)	0.421**(0.199)	0.546(0.409)	0.591(0.426)
In-group meaning	0.0587(0.240)	0.0606(0.240)	0.876*(0.483)	0.940*(0.519)
Out-group meaning	0.0881(0.239)	0.0948(0.239)	0.141(0.490)	0.0571(0.512)
Professor		−0.245(0.198)		0.213(0.442)
Engineering		0.154(0.232)		−0.957**(0.485)
Medical		0.528(0.401)		−1.585*(0.884)
Female		−0.297(0.250)		0.0124(0.527)
Constant	−3.541***(0.205)	−3.509***(0.296)	−1.021**(0.419)	−0.360(0.579)
Observations	2946	2946	110	110
Pseudo chi2	0.01	0.01	0.03	0.07

Note: Robust standard errors are in parentheses. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

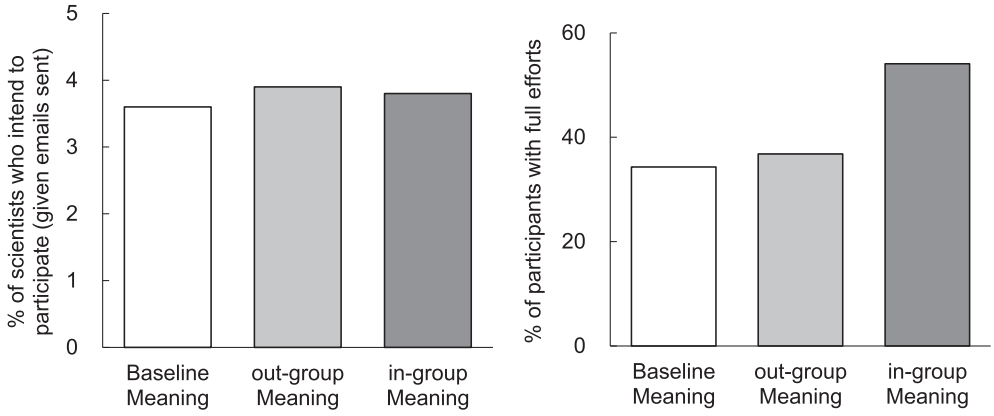

Fig. 2. In-group meaning causes a significant increase in scientists' efforts but not their intention to participate.

social proof has a positive influence on participation. Coefficient on social proof dummy was 0.42, significant at the 5% level. This means that social proof increased the odds that a scientist participated in public engagement by 52%. However, social proof has no significant effect on scientists' decision to exert full efforts by completing all the items (see columns (3) and (4) of Table 4). These results support H1.

5.3. The role of meaning

The effect of meaning on scientists' intention to participate and exert efforts in public engagement process was also considered. Fig. 2 shows the participation rate and percentage of participants who exerted full efforts across baseline meaning, in-group meaning, and out-group meaning conditions. The participation rate in the baseline-meaning group was 3.56% (35 out of 982); in-group meaning condition, 3.76% (37 out of 983); and out-group meaning condition, 3.87% (38 out of 981). The difference among the three meanings was not significant (χ^2=0.134, $p > 0.1$).

A sharp contrast was found for efforts making. Relative to the percentage of participants who exerted full efforts in control condition (12 out of 35 or 34.29%), the percentage of participants who exerted full efforts in in-group meaning condition was as high as 54.05% (21 out of 38; $\chi^2 = 2.847$, $p < 0.1$, odd's ratio = 2.255). The percentage of participants who exerted full efforts in out-group meaning condition was higher than that of the baseline-meaning group (36.84% vs. 34.29%), but the difference was not significant (χ^2=0.052, $p > 0.1$).

Logistic regression on intention to participate (see Columns (1) and (2) of Table 4) also reveals that in-group meaning and out-group meaning did not exert significant influence on this variable. Meanwhile, logistic regression on efforts (see Columns (3) and (4) of Table 4) shows that a scientist is more likely to exert full efforts in public engagement if he/she is under in-group meaning condition. The coefficient of in-group meaning is 0.940 with demographics, significant at 10% level. This means in-group meaning increases the odds that a scientist made efforts by 156%. Highlighting out-group meaning of public engagement did not lead scientists to participate or exert more efforts. These results partially support H2a and fully support H2b.

None of the control variables is directly linked with intention to participate. However, a higher probability to exert efforts was observed in scientists in the fields of physical and agricultural sciences. Compared with scientists in the fields of physical and agricultural sciences, studying engineer and medical sciences decreased the probability of exerting efforts (coefficient of −0.957 and −1.585, respectively). None of the other control variables is directly linked with exerting efforts.

6. Discussion

6.1. Theoretical contributions

Empirical studies on factors that facilitate science communication have focused mainly on evaluating the correlation between individual or organizational factors and intention to participate or frequency of self-reported behavior. These studies neglect the process by which intention to participate is formed and efforts are carried out (Zhang, 2015). Moreover, no previous studies explored the causal relationship of two social factors (i.e., information on other scientists' behavior and the meaning of such activities toward beneficiary groups) and scientists' behavior in public engagement process. Many prior studies also used survey methods in understanding scientists' behavior in public engagement activities. Field experiments, which detect causal effects through randomized assignment of treatment, have never been utilized.

This article contributes to the understanding of determinants for scientists' behavior in public engagement. It provides a process view by recognizing public engagement as a two-stage decision process, consisting of an intention to participate at the first stage and effort making at the second stage. Social proof and meaning are two important social factors that have differential effects on the two stages of scientists' public engagement process, which are causally identified by our innovative field experiment.

Informing scientists of their peers' participation in public engagement has significant effects at the first stage by inducing more scientists to participate in public engagement, but does not induce scientists to exert significantly more effects at the second stage. These results are consistent with the previous literature that found perceived descriptive norms as a driving factor of scientists' participation in public engagement. When scientists perceive that their peers participate in or support public engagement, they will be more likely to participate in public engagement (Poliakoff and Webb, 2007; Besley, 2014). The result also echoes the research stream of prevalence of social influence. For instance, hotel guests are more likely to reuse towels when they learned that the majority of other guests did so (Goldstein et al., 2008). By adopting the process view, the boundary of the social proof effects was also tested: peers' participation in public engagement has effects on scientists' intention to participate but not on the amount of efforts a scientist exerts after participation.

The results show that scientists' efforts in public engagement

largely depend on the meaning of public engagement. However, the intention to participate is not related to meaning. Meaning enhances scientists' belief that public engagement will have an impact. Such a belief increases external efficacy that further leads to more efforts being exerted (Besley et al., 2012). More importantly, the effectiveness of meaning was found to be largely dependent on the beneficiary groups: in-group meaning induces scientists to make efforts whereas out-group meaning does not. This finding is consistent with numerous studies in social psychology field that endorses the in-group/out-group disparity, and may also suggest scientists' efforts in public engagement are more motivated by social identification with and the perceived impact that they will make on the scientist community rather than increasing public welfare.

The present study also finds that discipline influences scientists' exertion of efforts in public engagement. Poliakoff and Webb (2007) fail to find the relationship between the field of discipline and scientists' intention to participate in public engagement. Besley et al., (2012) find that chemists are less likely than scientists in other fields to participate in public engagement. Our analysis suggests that scientists in the fields of physics and agricultural science are more likely to exert efforts in public engagement than those in the fields of engineering and medical science. Time constraint may explain these findings. Scientists working in the engineering and medical disciplines are usually more occupied than those in other disciplines.

Unlike past research that found scientists with higher rank engaging in science communication activities more frequently (Bauer and Jensen, 2011; Peters et al., 2008), we fail to establish a link between a scientist's academic rank and intention to participate intention or exert effort in public engagement. This could be attributed to the fact that previous research adopted a joint measure of academic status using both career level and publications; the present study used only career level. We also find no impact of gender on public engagement. This finding is consistent with Dudo (2012)'s findings, pointing out that ambiguity often characterizes gender's connection to scientists' public engagement. However, it is inconsistent with other studies that female scientists are more likely to engage in public engagement activities (Jensen, 2011; Jensen et al., 2008) and male scientists to be more active in public communication (Bentley and Kyvik, 2011; Kreimer et al., 2011; von Roten, 2011).

6.2. Policy implications

Public unawareness and misperception of climate and sustainability issues may lead to their unwillingness to change their individual behaviors, act collectively, or support policy making that address those issues. Communicating with the scientists help the public improve their knowledge of and action for climate and sustainability solutions. But scientist public engagement activities are inadequate, particularly in China. Lack of institutional support is one important reason for the undersupply of public engagement. While the US National Science Foundation requires education and public engagement elements in many types of its calls for proposals, Chinese funding agencies usually do not have much requirements.

Our findings suggest that without the need to make significant policy changes, simple “nudges” can trigger substantial increase of scientist participation and effort making in public engagement. These measures are inexpensive, by simply providing information of peers' participation and meaning to the science community. Because social proof and in-group meaning both link to the scientist community as scientists' significant others, the findings further suggest the importance to consider the community as a whole, instead of individual scientists. A more active science community would greatly improve the public engagement level and contribute to more science-based decision making and less misrepresented information of the whole society.

7. Conclusion

In this article, we conceptualize scientists' engagement in science communication as a two-stage process of participation intention and effort making. To identify causal effects of social proof and meaning on this process, a field experiment was conducted with scientists from all the faculty of tier-one universities in China. We find that social proof, which informs a scientist peer engagement, significantly improves scientists' participation intention but not their effort making. In-group meaning, which emphasizes benefits to the scientist community, increases real efforts made but does not improve participation rate.

Our findings reveal the opportunities of employing such inexpensive measures to promote science communication, which is particularly important for addressing climate and sustainable issues. This study has at least two limitations. First, as we were not able to measure mediating mechanisms in the field experiment, the study does not directly reveal why participation and efforts were increased by the experimental intervention. Second, this study only examined the issue among scientists in China, where the culture is collectivistic. Thus, future research, to contribute to climate and sustainability communication, can further investigate possible mechanisms or examine in the context of individualistic cultures.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclepro.2017.09.210.

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